# Gamma Ray Burst Discoveries with the Swift Mission

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## Outline

Long GRBs

Collapsar Understanding

Short GRBs

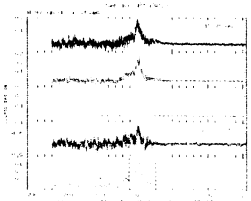
Afterglow

Reduced Trigger Threshold

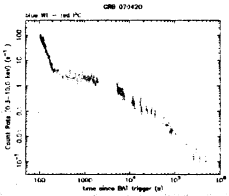
Hard X-ray Sky Survey

## *Swift* GRB from April 20

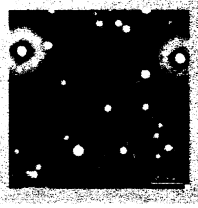
BAT prompt emission



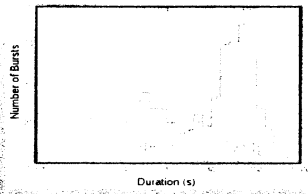
XRT afterglow lightcurve



UVOT images



## *Long GRBs*

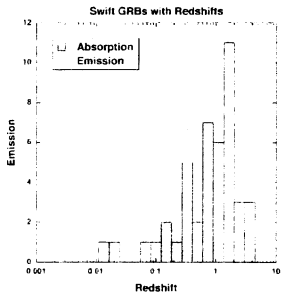



Kouveliotou et al. 1993

| | | | |
|---|---|---|---|
| 6.29 | 050904 | 2.35 | 070110 |
| 5.4* | 060927 | 2.31 | 070506 |
| 5.3 | 050814 | 2.30 | 060124 |
| 5.11 | 060522 | 2.20 | 050922C |
| 4.9 | 060510B | 2.04 | 070611 |
| 4.41 | 060223A | 1.95 | 050315 |
| 4.27 | 050505 | 1.71 | 050802 |
| 4.05 | 060206 | 1.55 | 051111 |
| 3.97 | 050730 | 1.51 | 060502A |
| 3.91 | 060210 | 1.50 | 070306 |
| 3.71 | 060605 | 1.49 | 060418 |
| 3.69 | 060906 | 1.44 | 050318 |
| 3.53 | 060115 | 1.31 | 061121 |
| 3.44 | 061110B | 1.29 | 050126 |
| 3.43 | 060707 | 1.26 | 061007 |
| 3.36 | 061222B | 1.17 | 070208 |
| 3.34 | 050908 | 0.97 | 070419A |
| 3.24 | 050319 | 0.94 | 051016B |
| 3.21 | 060926 | 0.84 | 070318 |
| 3.21 | 060526 | 0.83 | 050824 |
| 3.08 | 060607A | 0.76 | 061110A |
| 2.95 | 070411 | 0.70 | 060904B |
| 2.90 | 050401 | 0.65 | 050416A |
| 2.82 | 050603 | 0.62 | 070612A |
| 2.71 | 060714 | 0.61 | 050525A |
| 2.68 | 060604 | 0.54 | 060729 |
| 2.61 | 050820A | 0.44 | 060512 |
| 2.58 | 070529 | 0.125 | 060614 |
| 2.43 | 060908 | 0.089 | 060505 |
| 2.36 | 051109A | 0.033 | 060218 |

## 60 *Swift* Long GRB Redshifts

$< z > = 2.3$

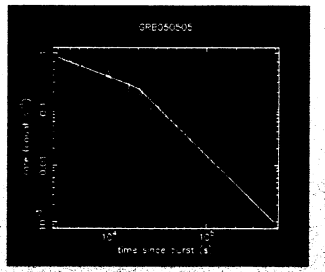



## GRB 050505

BAT

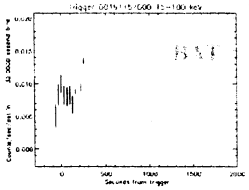
$z = 4.27$
Duration = 60 s

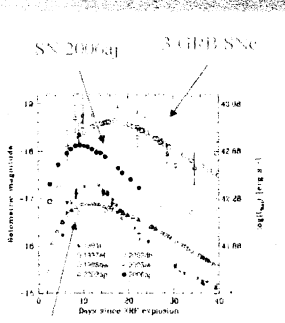
XRT



| z | GRB | Optical/IR Brightness |
|---|---|---|
| 6.29 | 050904 | J = 18 @ 3 hrs |
| 5.6 | 060927 | I = 16 @ 2 min |
| 5.3 | 050814 | K = 18 @ 23 hrs |
| 5.11 | 060522 | R = 21 @ 1.5 hrs |
| 4.9 | 060510B | J = 19 @ 2 hr |
| 4.41 | 060223A | V = 18 @ 1 min |
| 4.05 | 060206 | V = 17 @ 1 min |

## GRB 060218: GRB + Supernova






Super-long GRB - ~35 minutes

BAT, XRT, UVOT during GRB

z = 0.033 d = 145 Mpc

SN 2006aj SN Ib/c

$E_{iso}$ = few x $10^{49}$ erg ~ underluminous

$E_{peak}$ ~ 5 keV (XRF)

Campana et al., Mazzali et al., Pian et al., Soderberg et al.

# *Short GRBs*

## Short GRB - Current Status

*Swift* short GRB observations

- 18 short bursts detected (+ 2 from HETE)
- 78% with X-ray afterglow detected by XRT (95% long GRBs)
- 28% with optical detection (58% long GRBs)
- ~50% with host IDs

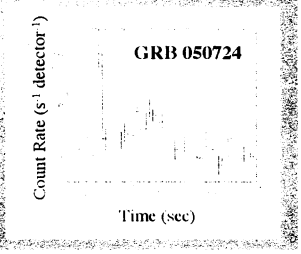
~1/2 shorts accompanied by soft extended emission up to 100 sec

Redshift range from z = 0.2 to ~2

- $\langle z \rangle_{short} = 0.6$
- $\langle z \rangle_{long} = 2.3$

Afterglow weaker than long GRBs

- $\langle F_X \rangle_{short} = 7 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$ (@ $t_0$+90s)
- $\langle F_X \rangle_{long} = 3 \times 10^{-9}$ erg cm$^{-2}$ s$^{-1}$ (@ $t_0$+90s)



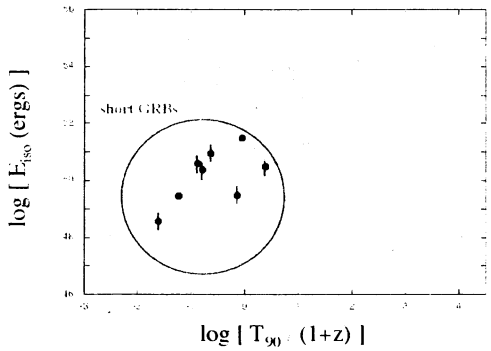

## Short GRB Redshifts

| | | | |
|---|---|---|---|
| 6.29 | 050904 | 2.04 | 070611 |
| 5.47 | 060927 | 1.95 | 050315 |
| 5.3 | 050814 | 1.71 | 050802 |
| 5.11 | 060522 | 1.55 | 051111 |
| 4.9 | 060510B | 1.51 | 060502A |
| 4.41 | 060223A | 1.50 | 070306 |
| 4.27 | 050505 | 1.49 | 060418 |
| 4.05 | 060206 | 1.44 | 050318 |
| 3.97 | 050730 | 1.31 | 061121 |
| 3.91 | 060210 | 1.29 | 050126 |
| 3.71 | 060605 | 1.26 | 061007 |
| 3.69 | 060906 | 1.13 | 060801 |
| 3.53 | 060115 | 1.17 | 070208 |
| 3.44 | 061110B | 0.97 | 070419A |
| 3.43 | 060707 | 0.94 | 051016B |
| 3.36 | 061222B | 0.84 | 070318 |
| 3.34 | 050908 | 0.83 | 050824 |
| 3.24 | 050319 | 0.83 | 061217 |
| 3.21 | 060926 | 0.76 | 061110A |
| 3.21 | 060526 | 0.70 | 060904B |
| 3.08 | 060607A | 0.65 | 050416A |
| 2.95 | 070411 | 0.62 | 070612A |
| 2.90 | 050401 | 0.61 | 050525A |
| 2.83 | 050603 | 0.55 | 051221A |
| 2.71 | 060714 | 0.54 | 060729 |
| 2.68 | 060604 | 0.48 | 050512 |
| 2.61 | 050820A | 0.41 | 061210 |
| 2.59 | 970828 | 0.296 | 050906 |
| 2.43 | 060908 | 0.258 | 050724 |
| 2.35 | 051109A | 0.225 | 050509B |
| 2.35 | 970508 | 0.125 | 050614 |
| 2.31 | 970228 | 0.111 | 061201 |
| 2.30 | 060121 | 0.089 | 060505 |
| 2.16 | 050922C | 0.033 | 060218 |

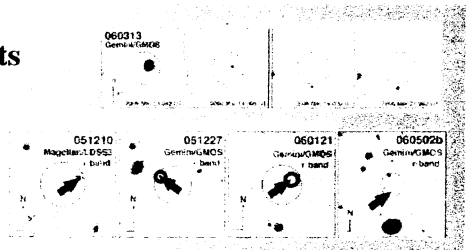
red = short GRBs

## Three Groups

*Swift* GRBs (mostly)



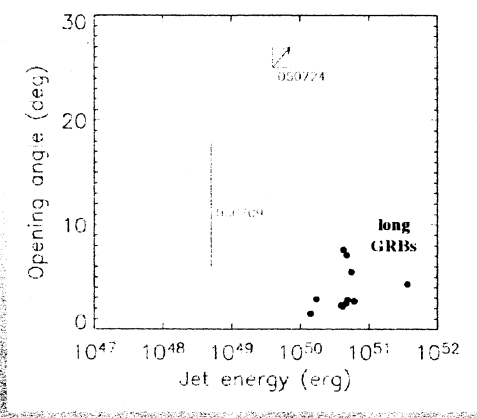

## Faint Short Hosts
## Large Distances




short host magnitudes

Berger et al. 2007

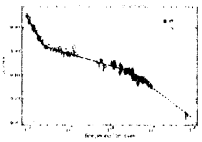
## Short GRB Beaming



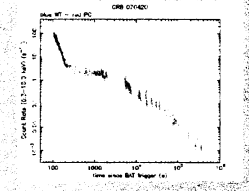

Burrows et al.

# *Afterglows*

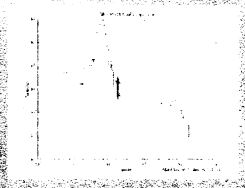
## Typical *Swift* X-ray Lightcurves



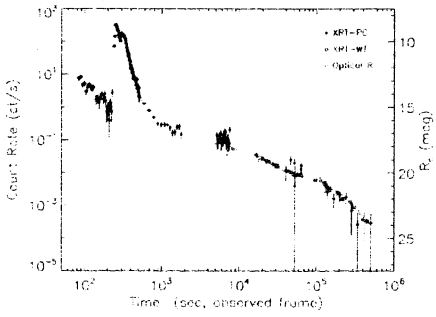
**50% with bright early component**



**>30% with flares**

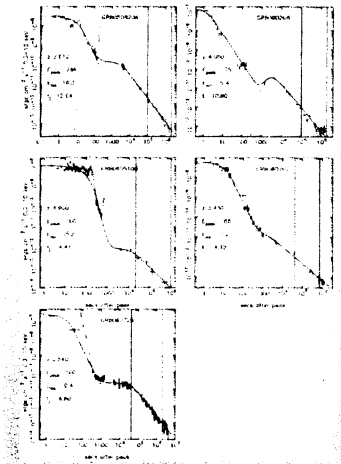


## Achromatic Jet Break - GRB 060526




z=3.21
jet angle = 7°

Dai et al. 2007



## Puzzling Data

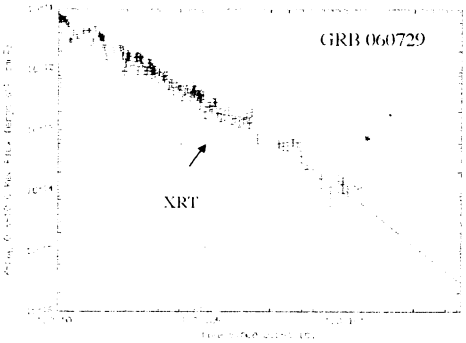
- Many GRBs do not show jet breaks
- In many other cases, optical and X-ray breaks are not coincident
- Complex shape of afterglow lightcurves makes jet break hard to find

Some argue that there is some evidence for achromatic breaks in many Swift GRBs

Willingale et al. 2007

Curran et al. 2007

## GRB 060729 - Long Afterglow




Limit on jet angle
$\theta > 25°$

(Sari et al. equation
$n = 0.1$ cm$^{-3}$
$\text{eff}_\gamma = 0.2$)

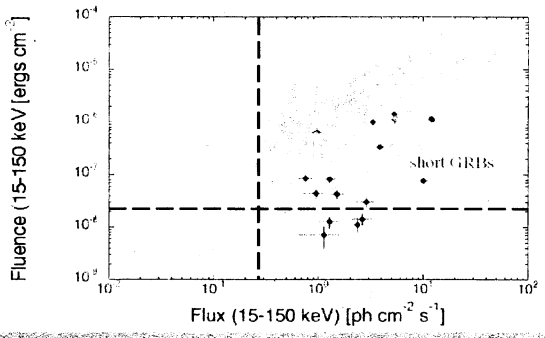
$E_\gamma > 2 \times 10^{51}$ erg

Grupe et al. 2007

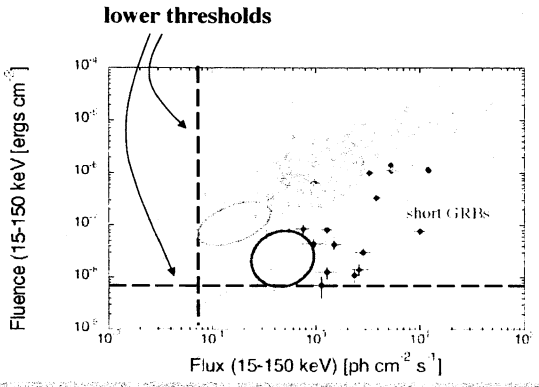
# *New Initiatives*

- **GRBs from slew data**
  - Collaboration with Grindlay group
  - Extra ~10 GRBs/yr
- **Lower BAT trigger thresholds**
  - 1-2 spacecraft slews per day
  - Real GRBs recognized by
    - XRT/UVOT detection
    - Coincidence with nearby galaxies
  - Real GRB rate unknown, perhaps 20 GRBs/yr

## BAT Fluence and Flux Limits

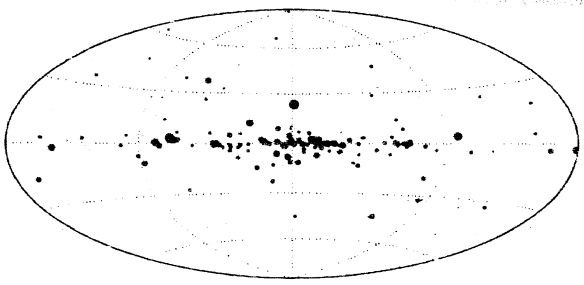



## BAT Fluence and Flux Limits



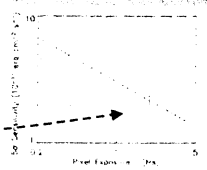

# *BAT Sky Survey*

## BAT Hard X-ray Survey



color coded by type
size proportional to log BAT rate

## Survey Results and Implications



- At 22 months 526 sources are detected
- **Sensitivity is ~1 mCrab all sky**
- Errors still dominated by statistics
- Early results
  - 15 gamma-ray blazars (one at z=3)
  - 3 symbiotic stars
  - **Absorbed AGN (Sy 2's) are ~60% of BAT AGN**
    - ⇒ Absorbed systems dominate AGN population in unbiased samples
- Implications
  - **First complete knowledge of local AGN population**
  - **7% of luminous (~L*) galaxies in local universe have AGN**